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(54) **SYSTEM AND METHOD FOR OPTIMIZING STORAGE AND TRANSCODING COSTS IN NETWORK DVR**

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H04N 21/442	(2011.01)
H04N 21/472	(2011.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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USPC 725/92, 58; 386/297

See application file for complete search history.

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(57) **ABSTRACT**

A method includes: storing, via a network storage device, information related to the playback history of a content playing device; receiving, via a network digital video recorder scheduler, a request to record requested content; receiving, via a network digital video recorder, the requested content in a first format and the requested content in a second format; and storing, via the network digital video recorder, only one of the requested content in the first format or the requested content in a second format based on the information related to the playback history.

7 Claims, 6 Drawing Sheets

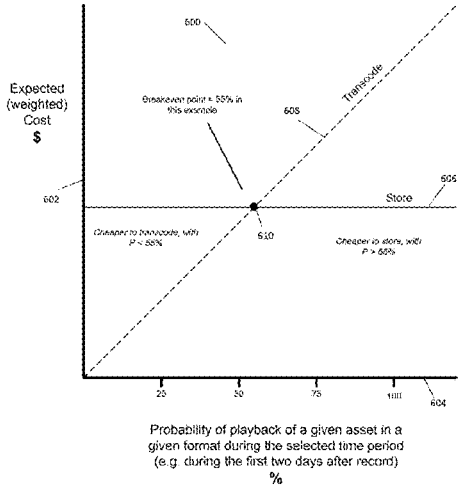

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FIG. 1

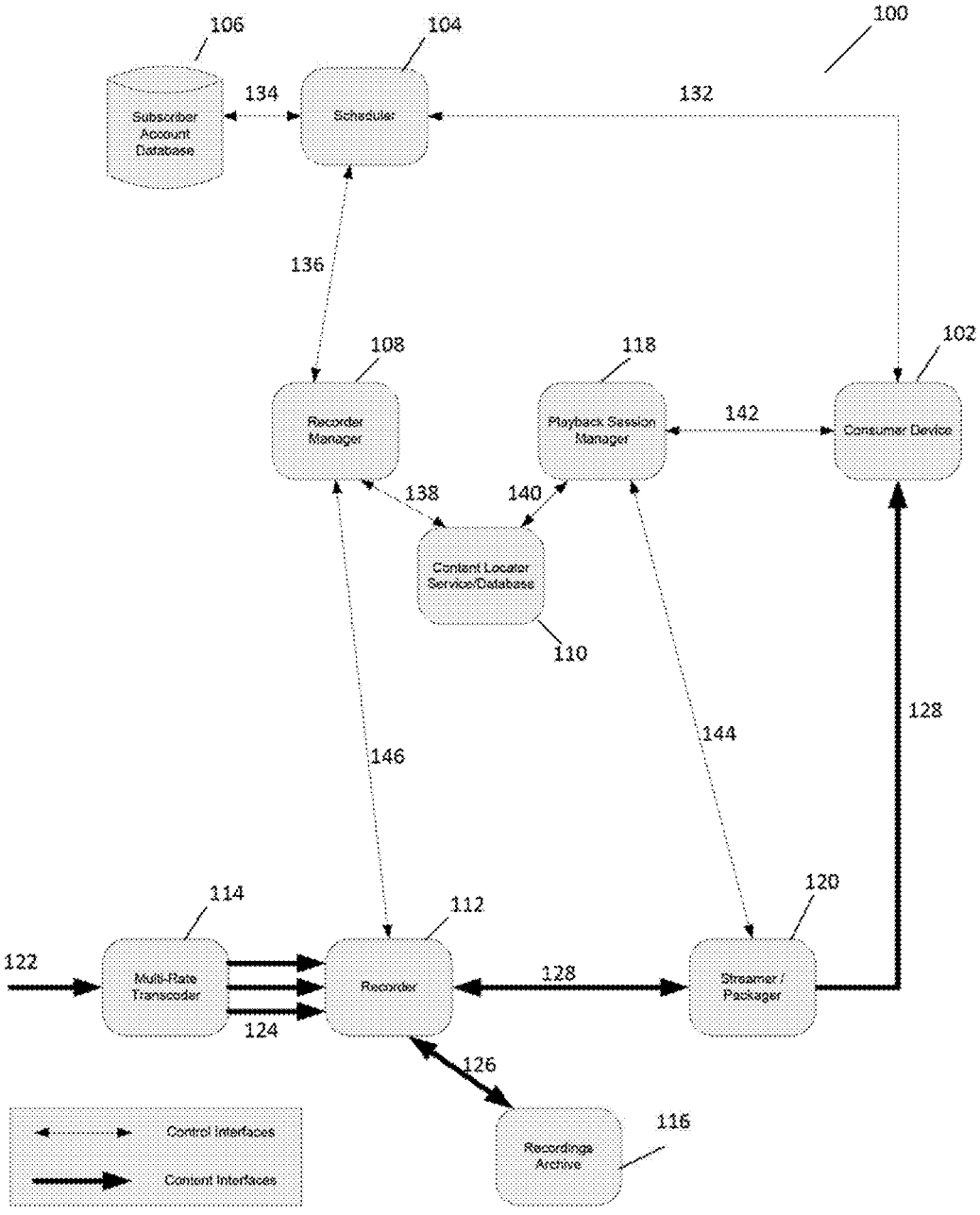

100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
132
134
136
138
140
142
144
146
Subscriber Account Database
Scheduler
Recorder Manager
Playback Session Manager
Consumer Device
Content Locator Service/Database
Multi-Rate Transcoder
Recorder
Streamer / Packager
Recordings Archive
Control Interfaces
Content Interfaces

FIG. 2

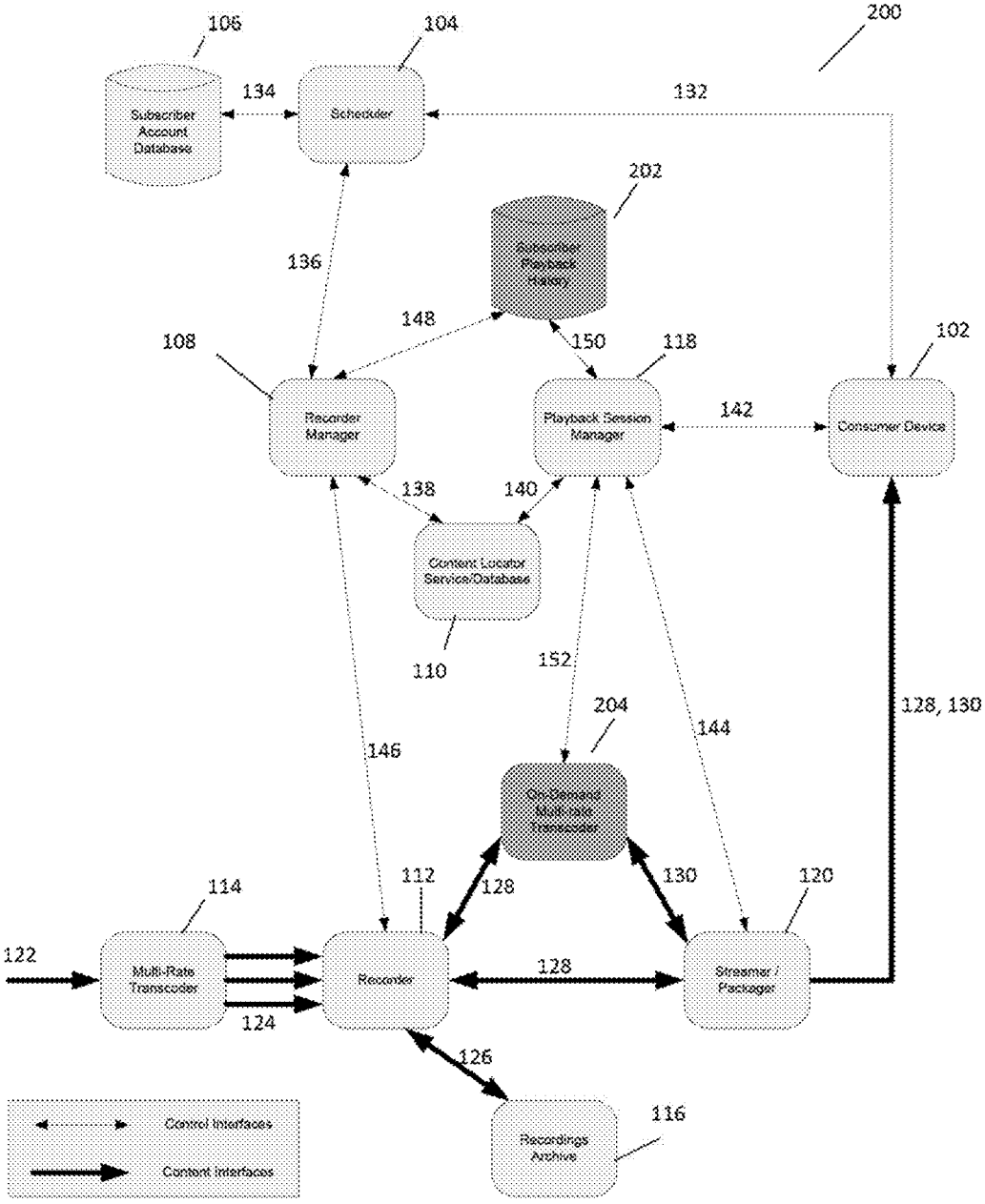

106
104
200
Subscriber Account Database
134
Scheduler
132
202
136
148
150
118
102
108
Recorder Manager
Playback Session Manager
142
Consumer Device
138
140
Content Locator Service/Database
110
152
204
128, 130
146
144
On-Demand Multi-rate Transcoder
112
128
130
120
114
122
Multi-Rate Transcoder
Recorder
128
Streamer / Packager
124
126
Control Interfaces
Content Interfaces
Recordings Archive
116

FIG. 3

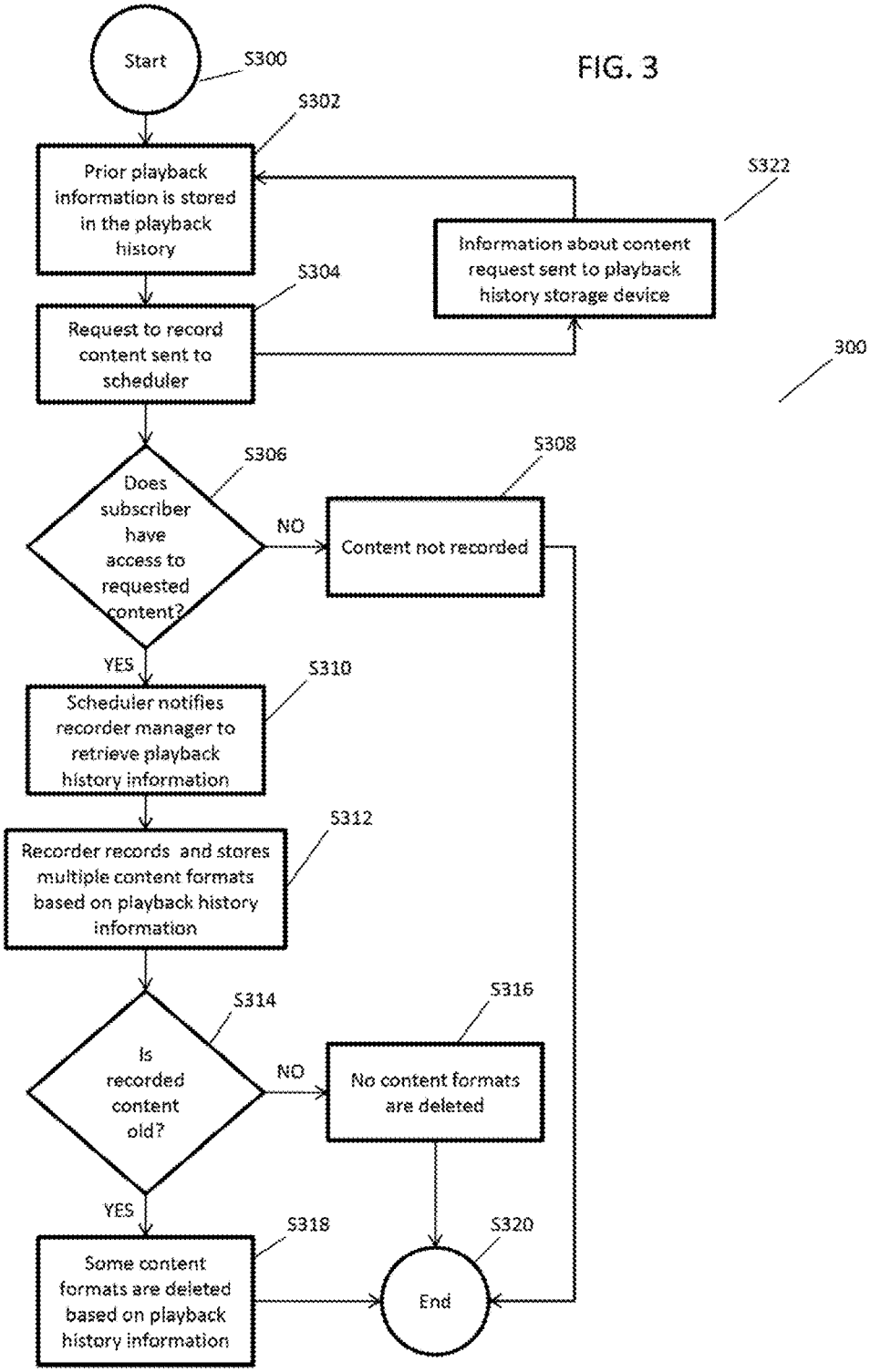

Start
S300
S302
Prior playback information is stored in the playback history
S322
Information about content request sent to playback history storage device
S304
Request to record content sent to scheduler
300
S306
Does subscriber have access to requested content?
NO
S308
Content not recorded
YES
S310
Scheduler notifies recorder manager to retrieve playback history information
S312
Recorder records and stores multiple content formats based on playback history information
S314
Is recorded content old?
NO
S316
No content formats are deleted
YES
S318
Some content formats are deleted based on playback history information
S320
End

FIG. 4

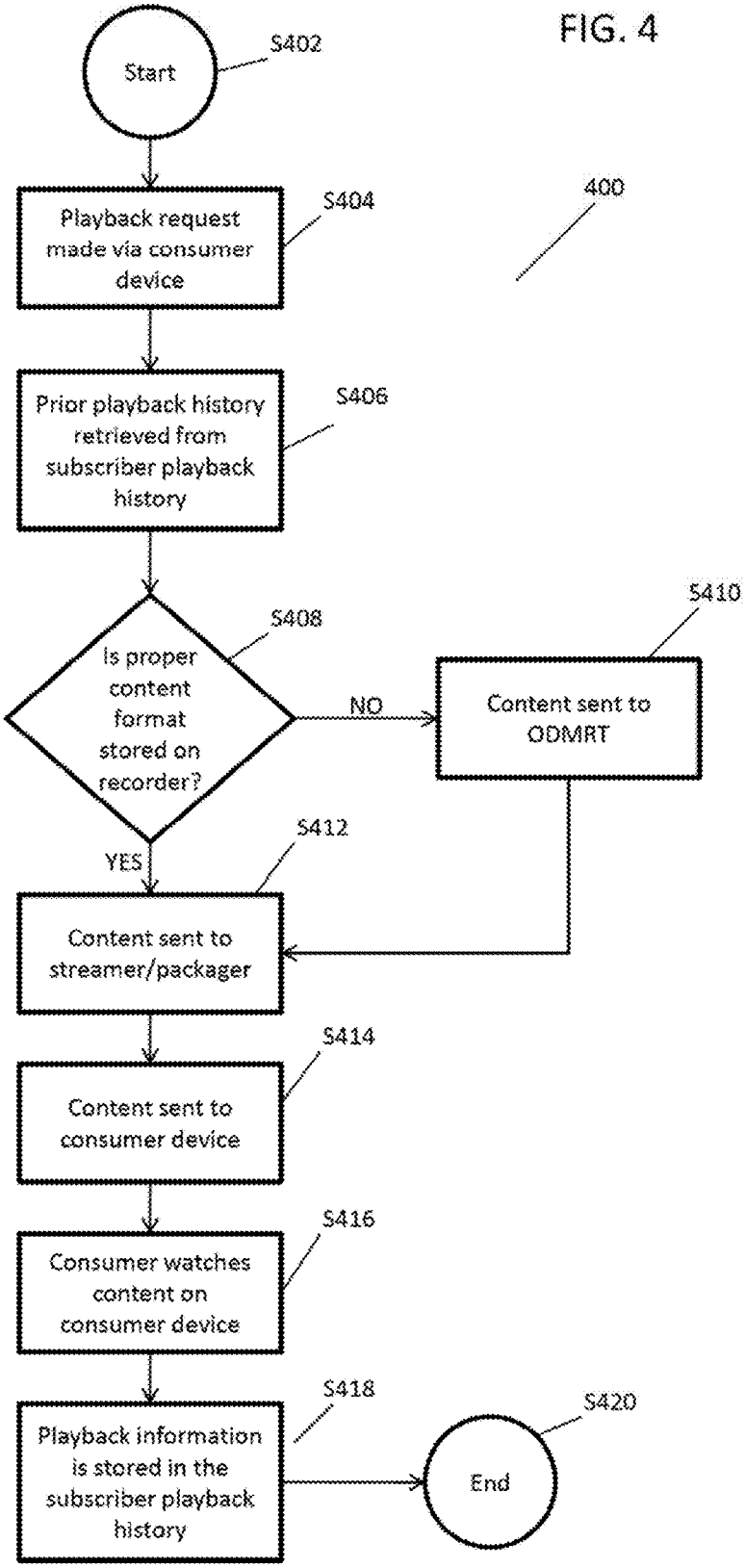

Start
S402
400
Playback request made via consumer device
S404
Prior playback history retrieved from subscriber playback history
S406
Is proper content format stored on recorder?
S408
NO
Content sent to ODMRT
S410
YES
Content sent to streamer/packager
S412
Content sent to consumer device
S414
Consumer watches content on consumer device
S416
Playback information is stored in the subscriber playback history
S418
End
S420

FIG. 5

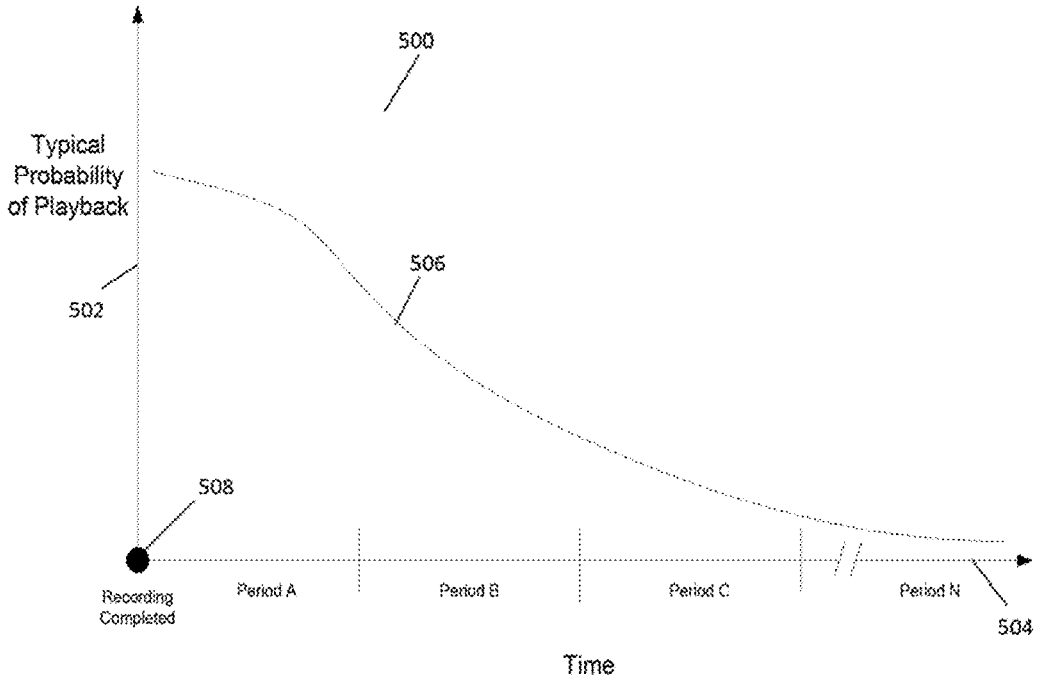
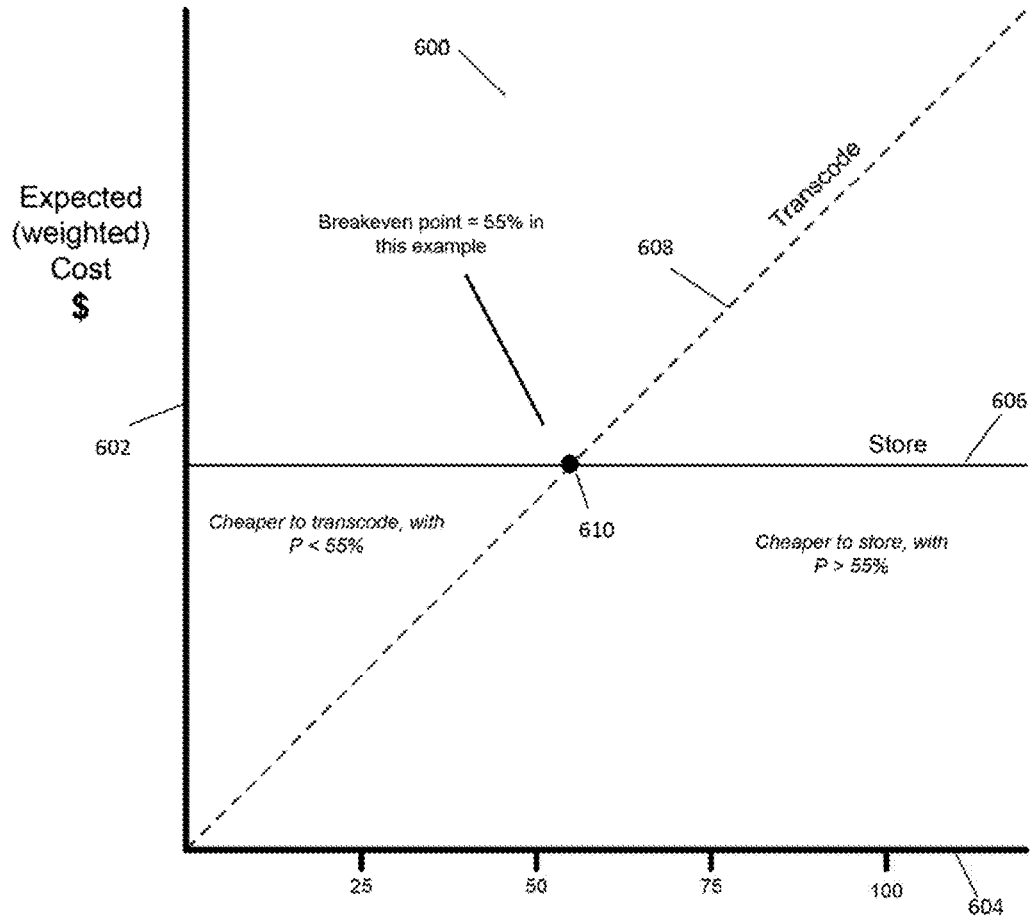

500
Typical Probability of Playback
502
506
508
Recording Completed
Period A
Period B
Period C
Period N
504
Time

FIG.6


600
Expected
(weighted)
Cost
$
602
Breakeven point = 55% in
this example
608
Transcode
605
Store
Cheaper to transcode, with
P < 55%
610
Cheaper to store, with
P > 55%
25
50
75
100
604
Probability of playback of a given asset in a
given format during the selected time period
(e.g. during the first two days after record)
%

SYSTEM AND METHOD FOR OPTIMIZING STORAGE AND TRANSCODING COSTS IN NETWORK DVR

The present application claims priority from U.S. Provisional Application No. 61/800,954, filed Mar. 15, 2013, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

The present disclosure generally deals with network digital video recorders (nDVRs).

BRIEF SUMMARY OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate example embodiments and, together with the description, serve to explain the principles of the present disclosure. In the drawings:

FIG. **1** illustrates a conventional nDVR system;

FIG. **2** illustrates another example nDVR system;

FIG. **3** illustrates a process by which content is stored and deleted;

FIG. **4** illustrates a process by which content is played back;

FIG. **5** illustrates a chart showing a cost analysis for the determination of whether to record or transcode content; and

FIG. **6** illustrates a chart showing the probability of watching recorded content over time.

DETAILED DESCRIPTION

Embodiments of the present disclosure relate to a method for optimizing storage and transcoding costs in network based Video-On-Demand (nDVR) systems.

Many network operators are considering the deployment of a network-based DVR as an alternative to the traditional in-home DVR, e.g., a DVR that is included in a set-top-box (STB). Some of the reasons the nDVR approach is attractive to operators include: it is a more effective way to support DVR content on multiple screens, it allows legacy STBs to support DVR functions, it allows for lucrative upsale opportunities, and it enables a new platform for targeted advertising.

In some cases, the content provider is required to store each subscriber's recordings uniquely, even in the case where multiple subscribers record the same content. This requirement significantly drives up the storage costs in an nDVR deployment, to the point where those costs may exceed the costs of traditional in-home DVR. This factor is aggravated with support for multiple screens. As used herein, multiple screens means multiple formats. If all necessary formats are recorded and stored uniquely for each recording for each subscriber, the storage costs increase even more.

One way to decrease the storage costs of nDVR would be to minimize the number of formats recorded for a given asset (in the minimal case, to record only a single, high quality format). In order to support nDVR on multiple screens, however, the system would have to be able to dynamically transcode content on the fly, to convert the content into a format (i.e., screen resolution) appropriate for the display device. However, this on-demand transcoding is costly, consuming expensive processing resources on a transcoding device.

Thus there is a trade-off between storage costs and transcoding costs, and it is in the interest of network operators to find the optimal (lowest cost) balance between these costs.

One approach to the storage/transcode tradeoff is to statically configure the system in some mode, to handle all recordings in one of the following ways: record and store all possible formats, record and store only one format and transcode others as needed, or record and store a few specific formats and transcode to others as needed.

However, none of these static approaches are likely to be optimal. Because viewing habits vary by user, the best storage/transcode choice for one recording is not likely to be the best choice for another recording. In other words the one size fits all approach is certainly not optimal.

Some recordings are likely to be played back in only one format, other recordings perhaps only in another format, others may be played on all possible formats, and yet others may not be played back at all (studies show that 20% or more of all DVR recordings are never watched). Furthermore some recordings are likely to be played back within a day or two after the recording, but are then never watched again (consider, for example, a recording of a regular season baseball game). Other recordings are likely to be watched many times over a long period of time (consider the recording of a child's favorite movie). Note that these two types of recordings are likely to exist within the same subscriber account.

In general, there are multiple viewers in a household sharing the same account, and those viewers are all scheduling recordings. Furthermore, each viewer has different viewing habits, with different preferred viewing devices depending on the type of program. There exists a need to develop an process to predict which formats are the most likely to be watched, how often they will be watched and when they will be watched based on past viewing history.

FIG. **1** illustrates a conventional nDVR system **100**.

As shown in the figure, system **100** comprises consumer device **102**, scheduler **104**, subscriber account database **106**, recorder manager **108**, content locator database **110**, recorder **112**, multi-rate transcoder **114**, recordings archive **116**, playback session manager **118**, and streamer/packager **120**.

Control interfaces are shown as thin connecting lines **132**, **134**, **136**, **138**, **140**, **142**, **144** and **146** and content interfaces are shown as thick connecting lines **122**, **124**, **126**, **128** and **130**. A control interface is an interface where instructions or commands are communicated, and a content interface is an interface where content is moved from one place to another.

Consumer device **102** can be any device on which content can be viewed and/or recordings scheduled (e.g., recordings may be scheduled via one consumer device on an account, and then played back on the same or different devices associated with that account). Non-limiting examples of consumer device **102** include a television, desktop computer, laptop computer, tablet computer and cellular phone. Consumer device **102** may also include a graphical user interface (GUI) that will provide the consumer to request content delivery, change settings, etc.

Scheduler **104** receives scheduling requests from consumer device **102**, determines the accessibility of content and schedules content recordings.

Subscriber account database **106** stores account information of subscribers. Non-limiting examples of information stored include account number, customer name, address, subscription type, privileges, the types of devices used to view content, and specific device identities, e.g., devices may have to uniquely register to an account before they may be allowed to schedule or watch recordings for security reasons.

Recorder manager **108** receives information from scheduler **104** regarding the content to be recorded. Recorder man-

ager **108** also relays information to recorder **112** regarding the type(s) of content and format(s) that need to be recorded for future viewing.

Content locator database **110** receives information from recorder manager **108** regarding the location of specific recorded content, information that is needed upon playback of the desired recorded content. Content locator database **110** may be in the form of a lookup table, spreadsheet, or other data storage format that would provide a mechanism by which to locate a specific content.

Recorder **112** records and stores the desired content. Recorder **112** records the content in digital format and saves it to a disk drive, USB flash drive, SD memory card or any other mass storage device designed to store large files like video content. Recorder **112** receives one or more transcoded content formats from multi-rate transcoder **114**, based on the information regarding types and formats of content from recorder manager **108**.

Multi-rate transcoder **114** serves to convert one type of encoded content to one or more other types of encoded content, such that the transcoded content may be viewed easily by different devices that require different video and/or audio formats (e.g., a high definition television versus a smart phone) and/or bitrates.

Recordings archive **116** is a storage device that can store older content that has not been viewed for some time. Further, in some situations, the cost associated with storing content in recordings archive **116** may be lower than the cost associated with storing content in recorder **112**. Further, retrieving content from recordings archive **116** may take more time, from receipt of a content request, than retrieving content from recorder **112**. Recordings archive **116** may include physical storage and/or memory media such as RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices that have the capacity to store content.

Playback session manager **118** communicates with consumer device **102** when it is time to watch a video that was previously recorded, and also with content locator database **110** to determine the location of the desired content. Playback session manager **118** knows which type of consumer device **102** is making the content request, and forwards that information along to streamer/packager **120**.

Streamer/packager **120** is operable to provide content to consumer device **102** and to communicate with recorder **112** in order to assure that the content provided to consumer device **102** is provided in the appropriate format.

In operation, a consumer will determine that she wants to record a certain type of content. For this example, the content is a movie. The consumer will activate consumer device **102** and, using a user interface (not shown) on consumer device **102**, inputs a request to record the movie. The request is sent, via control interface **132**, to scheduler **104**, which performs two functions. First, scheduler **104** checks, via control interface **134**, the information contained in subscriber account database **106** to confirm that the consumer has the appropriate account and access privileges to record the desired movie. If the consumer does not have the appropriate account or access privileges, then the movie will not be recorded. If the consumer does have the appropriate account or access privileges, then scheduler **104** confirms that the movie will be recorded and sets up the recording.

The information generated by scheduler **104** is then sent, via control interface **136**, to recorder manager **108**. Recording manager **108** will record the content in whatever format was originally requested by consumer device **102**. For example, if consumer device **102** requests the content in a standard definition format, recording manager **108** will record the content in a standard definition format. Similarly, if consumer device **102** requests the content in a high definition format, recording manager **108** will record the content in a high definition format. Recorder manager **108** knows via static configuration the 'location' on content to record, so no special lookup is required. Content locator database **110** finds where the recorded contents have been made/stored—this is because there may be actually many instances stored in recorder **112**. So after the recording is configured on a specific instance of recorder **112**, records manager **108** updates content locator database **110** with the location information for that particular recording. This location information in content locator database **110** is consulted upon playback, when the specific recording needs to be found.

Recorder **112** then records the appropriate content formats **124** of the movie provided by multi-rate transcoder **114**, which had previously taken the highest quality content version **122** and transcoded it into content formats **124** most likely to be recorded by a consumer. It should be noted that there are typically many instances of recorder **112**, which scale up as necessary to handle the ingest and recording of many assets, mostly as a function of the number of subscribers supported. After this is complete, the content is ready to be viewed by the consumer.

In order to watch the content, the consumer may request to view the movie using the user interface on consumer device **102**. The request is sent to playback session manager **118**, via control interface **142**, and playback session manager **118** determines which instance of the recorder **112** contains the movie by communicating with content locator database **110** via control interface **140**. Playback manager **118** then sends the viewing request to streamer/packager **120** via control interface **144**. Streamer/packager **120** retrieves desired content format **128** from appropriate recorder **112** and streams desired content format **128** to consumer device **102** for the consumer to view.

System **100** is still limited in its approach to the storage/transcode tradeoff. As mentioned above, system **100** will be statically configured in some mode, to handle all recordings in one of the following ways: record and store all possible formats, record and store only one format and transcode others as needed, or record and store a few specific formats and transcode to others as needed.

Aspects in accordance with the present disclosure provide an alternative system and method managing storage/transcoding in a nDVR system. These will now be described with greater detail with reference to FIGS. **2-5**.

FIG. **2** illustrates another nDVR system.

As shown in the figure, nDVR system **200** includes all of the components of nDVR system **100** with the addition of subscriber playback history **202** and on-demand multi-rate transcoder (ODMRT) **204**.

Subscriber playback history **202** is a database that stores information provided to it by playback session manager **118**. Non-limiting examples of information stored on subscriber playback history **202** includes a record of playback operations for a consumer account. In some example, information may include the billing account number, playback device and capabilities, asset requested (including asset metadata such as Series Name, Genre, Episode/Title, Audience, Show Type, Parental Rating, etc.), time and date of session start, session type (i.e., VOD, nDVR, SDV), trick play usage and the type of delivery network (i.e., service provider managed, WiFi, 3G, etc.). In an example embodiment, information stored on subscriber playback history **202** includes a record of every playback operations for every consumer account. Note that the

data recorded may not just be from nDVR sessions, but also VOD sessions as well as switched digital video (SDV) sessions.

Processed sessions may be captured in subscriber playback history **202** and marked accordingly. In some embodiments, all processed sessions may be captured in subscriber playback history **202** and marked accordingly. The reason VOD and SDV sessions may captured as well is to give the system a richer view into what types of content is watched, how often it is watched, and in which formats. This complete viewing history may be helpful in making predictions of future viewing of individual nDVR recordings.

ODMRT **204** is a transcoder that serves to convert one type of encoded content to one or more other types of encoded content at the point of playback, if the desired format is not stored on the recorder.

The operation of system **200** will be further described with reference to FIGS. **3-4**.

FIG. **3** illustrates a method by which content is stored and deleted.

As shown in the figure, method **300** starts (S**300**) and any prior information regarding playback history is stored (S**302**) for future reference.

Returning to FIG. **2**, the playback history information is stored within subscriber playback history **122**.

Returning to FIG. **3**, a request to record content is sent to a scheduler (S**304**). All information regarding the request (content type, type of device from which the request originates, etc.) is sent to a storage device (S**322**), where it is stored for future reference). In situations where the subscriber requesting the content does not have access to the content, then the information regarding the request will not be sent to the storage device. In particular, since the content will not be watched, such information is not relevant.

Returning to FIG. **2**, consumer device **102** sends a request, via control interface **132**, to record content to scheduler **104**, and information relating to the request is sent to subscriber playback history **122**, via control interface **148**, for future reference.

Returning to FIG. **3**, it may be determined if the subscriber requesting the content has access to the requested content (S**306**). If the subscriber does not have access to the requested content (NO at S**306**) then the content is not recorded (S**308**) and method **300** ends (S**320**). If the subscriber does have access to the requested content (YES at S**306**), then the schedule notifies the recorder manager to retrieve any available playback information (S**310**).

Returning to FIG. **2**, scheduler **104** checks, via control interface **134**, the information contained in subscriber account database **106** to confirm that the consumer has the appropriate account and access privileges to record the desired movie. If the consumer does not have the appropriate account or access privileges, then the movie will not be recorded. If the consumer does have the appropriate account or access privileges, then scheduler **104** confirms that the movie will be recorded and sets up the recording.

The information generated by scheduler **104** is then sent, via control interface **136**, to recorder manager **108**. Recorder manager **108** then communicates, via control interface **148**, with subscriber playback history **202** to determine if the requested content, or something similar thereto, has been previously requested and/or viewed.

Returning to FIG. **3**, the recorder then records and stores the requested content in different formats based on the information retrieved from the playback history information (S**312**).

Returning to FIG. **2**, if the requested content, or something similar thereto, has not been previously requested or viewed, then recorder manager **108** may tell recorder **112**, via control interface **146**, to record standard format(s) based on the content being requested.

If the requested content, or something similar thereto, has been previously requested or viewed, then subscriber playback history **202** may determine which devices were used to view the similar content in past. That information would be forwarded to recorder manager **108**, via control interface **148**, which would then communicate with recorder **112**, via control interface **146**, such that recorder **112** would record the format(s) most likely to be viewed later by the consumer, thus saving storage and transcoding costs. A more detailed discussion of cost/benefit analysis of content storage versus transcoding will be described later with reference to FIG. **6**.

Returning to FIG. **3**, after a predetermined amount of time, the system will check the dates on which the requested content was recorded to determine if the content is old or whether it has been accessed one or more times (S**314**). For example, some content, like a television series, may be watched over the course of a week or two by several different family members, so it may not be desirable to use age as the only factor. If the requested content is not old (NO at S**314**) the no formats of the requested content are deleted (S**316**) and method **300** ends (S**320**). If the requested content is old and has not been accessed recently (YES at S**316**) then some content formats will be deleted based on the playback history information (S**318**) and method **300** ends (S**320**).

Returning to FIG. **2**, after content **124** has been recorded, system **200** will periodically check to see if content **124** is considered "old". The user may provide a definition of "old" (for example, 5 days after recording), or system **200** may define "old" if a definition is not provided by the user. The definition of "old" may also change based on the type of content. For example, a user may only wish to keep a recorded baseball game as "new" for 2 days, but it may be desirable to keep a recorded movie as "new" for 2 months.

If content **124** is determined to be "old", then system **200** will consult subscriber playback history **202** to determine the content format that is most likely to be viewed by the user in the future. When the determination is made regarding the most likely format to be played in the future, all other formats of content **124** are deleted in order to save storage space on system **200**. For example, if the requested content is a movie and the consumer typically watches movies on a tablet computer, then system **200** would delete all formats of content **124** except for the format that is best suited for viewing on a tablet computer. As another example, if the requested content is a baseball game and the consumer typically watches baseball games on an HD television, then system **200** would delete all formats of content **124** except for the HD format.

FIG. **4** illustrates a method by which content is played back.

As shown in the figure, method **400** starts (S**402**) and a request is made to play back previously recorded content (S**404**).

Returning to FIG. **2**, consumer device **102** sends the request to play back content **124** to playback session manager **118**, via control interface **142**, and playback session manager **118** sends all relevant information regarding the playback request to subscriber playback history **202**, via control interface **150**, and to ODMRT **204** via control interface **152**. For purposes of discussion, let the request for content be originated from a tablet computer.

Returning to FIG. **4**, all prior playback history is retrieved from the subscriber playback history (S**406**).

Returning to FIG. **2**, subscriber playback history **118** will provide all relevant information regarding pasts requests (including the type of device requesting the content, and the playback format of the content) for the same (or similar) to playback session manager **118** via control interface **150**.

Returning to FIG. **4**, it may then be determined whether the proper content for playback is stored on the recorder (S**408**). If the proper content is stored on the recorder (YES at S**408**), then the content is sent to the streamer/packager (S**412**) for delivery to the consumer device (S**412**).

Returning to FIG. **2**, If the similar content requested in the past was also requested by a tablet computer, then, based on the communication between subscriber history playback **202**, recorder manager **108** and recorder **112** described above, the appropriate content format for a tablet computer may be available on recorder **112**. In that case, content **128** is transferred from recorder **112** to streamer/packager **120** for delivery to consumer device **102**, in this case a tablet computer.

Returning to FIG. **4**, the consumer watches the content on the consumer device (S**416**), and all information regarding the current playback session is stored in the subscriber playback history (S**418**), and method **400** ends (S**420**).

Returning to FIG. **2**, after streamer/packager **120** sends content **128** to consumer device **102**, the consumer watches content **128**. Information regarding the current playback session is also sent to subscriber playback history **202** via control interfaces **142** and **150**, in order to provide more data for future content requests.

Referring to FIG. **4**, if the proper content is not stored on the recorder (NO at S**408**), then the content may be sent to the ODMRT for transcoding (S**410**) prior to sending the content to the streamer packager (S**412**).

Returning to FIG. **2**, now consider the alternative case where the similar content requested in the past was not requested by a tablet computer, but by a HD television. In this case, recorder **112** may not have a format stored that is compatible with a tablet computer, and therefore ODMRT **204** may need to transcode the content **128** when playback is requested. The transcoded content **130** may be transferred to streamer/packager **120** for delivery to consumer device **102**, the tablet computer in this case.

Returning to FIG. **4**, the remaining processes of method **400** (S**412**-S**420**) are executed as described above, and method **400** ends.

Over time, as subscriber playback history **202** records more and more information regarding playback history, the decisions made regarding which formats to store versus transcode may be more accurate.

In the above examples, system **200** may automatically determines what type of content to store and transcode.

The process for determining the format(s) of content to record versus transcode will be discussed in more detail with reference to FIG. **6**, but it is appropriate to first address the relationship between the probability of watching recorded content as a function of the time elapsed since recording the content, which will be discussed in further detail with reference to FIG. **5**.

FIG. **5** illustrates a chart **500** showing the probability of watching recorded content over time.

As shown in the figure, chart **500** includes probability axis **502**, time axis **504**, origin **508** and probability curve **506**. Time axis **504** may be subdivided into smaller increments of time, shown as periods A-N on chart **500**. In an example embodiment, periods A-N are 3-5 day increments, however embodiments be carried out using any other designated time increments.

In general, right after a recording is completed, i.e., from time t=0 at origin **508** to the end of period A, the probability of watching the recorded content is highest, and the overall probability of watching recorded content decreases over time, as shown generally by probability curve **506**. For example, if a user records a baseball game but does not watch it within 2 days of recording it, it is very unlikely that the game will be watched, as other, more recent games may have been recorded for viewing. As another example, if a user records the evening news but does not watch it the next day, the likelihood of it being watched is very low, as the news will no longer be current, and evening news program will be broadcast the next evening. As yet another example, if a user records an episode of a popular sitcom and it is not watched by the time the episode is aired the next week, the likelihood of the recorded episode being watched is very low.

It should be noted that probability curve **506** depicts a typical, expected probability of playback for a particular content, and no assumptions are made based on the general probability curve **506**. Instead, the probability curve for each piece of content is calculated based on the viewing history for the subscriber account, as described by the examples provided above.

FIG. **6** illustrates a chart showing a cost analysis for the determination of whether to record or transcode content.

As shown in the figure, chart **600** includes expected (weighted) cost axis **602**, playback probability axis **604**, storage cost line **606**, transcode cost line **608** and breakeven point **610**.

In general, the cost to store a piece of content remains constant regardless of the probability of playback, noted by the flat storage cost line **606**. In general, the cost to transcode a piece of content is higher than it is to store that same piece of content. Therefore, as the probability of playback increases, it is much more cost effective to have the content stored instead of transcoding it. This is shown generally by the upward sloped transcode cost line **608**. The point at which storage cost line **606** and transcode cost line **608** intersect is breakeven point **610**. At breakeven point **610**, the cost to transcode and the cost to store are equal. In the example shown in chart **600**, the breakeven point occurs when the probability of playback is 55%. As discussed above, this means that when the probability of viewing the content is less than 55%, the desired content format should not be stored in recorder **112**, but transcoded when the playback request is received. Conversely, when the probability of viewing the content is greater than 55%, the desired content format should be stored in recorder **112** in order to reduce costs. When the probability of viewing the content is exactly 55%, then the content may either be stored in the desired format or not stored, as the cost for either option is the same.

The breakeven point may be different for different types of content, so each piece of content may have a unique expected cost vs. playback probability chart. The following example details a scenario in which decisions are made to transcode and/or record content.

In a first example, consider a subscriber account having the following devices: a HD device that is compatible with H.264, known as the mezzanine format; a standard definition device that is compatible with MPEG-2, known as format X; a tablet device that may use an adaptive bit rate and is compatible with H.264, 720×480 resolution, 2000 Kbps, known as format Y; and a smartphone that may use an adaptive bit rate and is compatible with H.264, 360×240 resolution, 440 Kbps, known as format Z.

In this example, the mezzanine format (H.264) is the highest quality format. For purposes of discussion, let this format

always be recorded be used to transcode all other formats as necessary. Further, let there are three different time periods: Period A (0-2 days after recording); Period B (2-6 days after recording); and Period C (6-10 days after recording).

The following table outlines some assumed costs:

	Format X	Format Y	Format Z
Cost to record 1 hour and store for period A	$Store_{X\text{-}A}$ = $1.00	$Store_{Y\text{-}A}$ = $0.80	$Store_{Z\text{-}A}$ = $0.50
Cost to transcode 1 hour	$Trans_X$ = $2.00	$Trans_Y$ = $2.50	$Trans_Z$ = $3.00
Cost to store 1 hour for period B	$Store_{X\text{-}B}$ = $1.20	$Store_{Y\text{-}B}$ = $1.00	$Store_{Z\text{-}B}$ = $0.70
Cost to store 1 hour for period C	$Store_{X\text{-}C}$ = $1.20	$Store_{Y\text{-}C}$ = $1.00	$Store_{Z\text{-}C}$ = $0.70

The main initial job of the recorder manager may be to decide which formats to record. To determine this, the recorder manager may only be concerned with the probability of playback during the first time period (Period A). The probability of playback during later time periods may be used to determine if and when already stored formats are deleted.

In this example, let the following playback percentages for period A be as follows: Percentage of all recordings played back in format X within period A: $P_{All\text{-}X\text{-}A}$=50%; Percentage of similar recordings played back in format X within period A: $P_{Sim\text{-}X\text{-}A}$=10%; Percentage of all recordings played back in format Y within period A: $P_{All\text{-}Y\text{-}A}$=15%; Percentage of similar recordings played back in format Y within period A: $P_{Sim\text{-}Y\text{-}A}$=55%; Percentage of all recordings played back in format Z within period A: $P_{All\text{-}Z\text{-}A}$=10%; Percentage of similar recordings played back in format Z within period A: $P_{Sim\text{-}Z\text{-}A}$=15%; and Similarity weighting factor (% confidence factor—how closely does the recording in question match the similar recordings from account history): Sim-Factor=90%.

Based on the data above, it is clear that there are many similar playback operations on this account (the Sim-Factor is a high 90%). The history indicates that similar recordings are played back frequently on the Tablet (Format Y), but not so frequently on the standard definition device (Format X) nor on the smartphone (Format Z).

To determine the relative cost of storing versus transcoding for format X (MPEG-2), the following comparison is made: relative cost to record and store:

$Store_{X\text{-}A}$=$1.00;

Relative weighted cost to transcode: (Sim-Factor*$P_{Sim\text{-}X\text{-}A}$+[1-Sim-Factor]*$P_{All\text{-}X\text{-}A}$) *$Trans_X$=(0.90*$0.10)+($0.10*$0.50) *$2.00=$0.28.

The weighted cost to transcode to Format X is less than the cost to store. The reason this is that case is that similar programs are rarely played back in this format. So it does not make sense to record this format up front, instead to transcode to this format only if requested (which is unlikely).

To determine the relative cost of storing versus transcoding for format Y (ABR for tablet), the following comparison is made: relative cost to record and store:

$Store_{Y\text{-}A}$=$0.80;

Relative weighted cost to transcode: (Sim-Factor*$P_{Sim\text{-}Y\text{-}A}$+[1-Sim-Factor]*$P_{All\text{-}Y\text{-}A}$) *$Trans_Y$=(0.90*$0.55)+($0.10*$0.15) *$2.50=$1.27.

The weighted cost to transcode to Format Y is more than the cost to record and store. The reason this is that case is that similar programs are frequently played back on the tablet. Thus a playback request for tablet is likely for this program too, and it is thus cheaper to record and store this format up front (thereby avoiding a likely and costly transcoding operation in the future).

To determine the relative cost of storing versus transcoding for format Z (ABR for smartphone), the following comparison is made: relative cost to record and store:

$Store_{Z\text{-}A}$=$0.50;

Relative weighted cost to transcode: (Sim-Factor*$P_{Sim\text{-}Z\text{-}A}$+[1-Sim-Factor]*$P_{All\text{-}Z\text{-}A}$) *$Trans_Z$=(0.90*$0.15)+($0.10*$0.10) *$3.00=$0.44.

The weighted cost to transcode to Format Z is less than the cost to store. The reason this is that case is that similar programs are rarely played back in this format (for Smart Phone). So it does not make sense to record this format up front, instead to transcode to this format only if requested, which is unlikely to happen.

Within this example, it may also necessary to determine if and when to delete a given format once the content has been stored past time period A. Based on the above calculations, the recorder manager decides to record two formats for this asset: the mezzanine format (H.264 High Def) and format Y (ABR for the tablet). With respect to this recording the recorder manager may periodically check the viewing history of similar assets on this account to determine how long it makes sense to store format Y. There is an ongoing cost to store this media file, but the value of holding that file decreases over time as the likelihood the user may request playback decreases.

Formats X and Z are irrelevant at this point since they were not recorded and stored, thus there is no consideration to whether or not those formats should be deleted.

The relevant data for the decision for format Y in period B may determined from viewing history on the account. For purposes of discussion, in this example, let the relevant data be as follows:

- Percentage of all recordings played back in format Y in period B: $P_{All\text{-}Y\text{-}B}$=10%;
- Percentage of similar recordings played back in format Y in period B: $P_{Sim\text{-}Y\text{-}B}$=5%;
- Similarity weighting factor (% confidence factor—how closely does the recording in question match the similar recordings from account history): Sim-Factor=90%.

For purposes of discussion, in this example, to determine the relative cost of storing versus transcoding for format Y in period B, the following comparison is made: relative cost to record and store:

$Store_{Y\text{-}B}$: $1.00;

Relative weighted cost to transcode: (Sim-Factor*$P_{Sim\text{-}Y\text{-}B}$+[1-Sim-Factor]*$P_{All\text{-}Y\text{-}B}$) *$Trans_Y$=(0.90*$0.05)+($0.10*$0.10) *$2.50=$0.14.

Since the relative weighted cost to transcode ($0.14) is less than the relative cost to store ($1.00), then format Y should be deleted at the start of Period B (i.e., at the end of Period A).

Naturally, since the event is deleted in period B, there is no need to check the data for period C. The recorder manager would not attempt to determine the period C data in this example, since that would be unnecessary work, e.g., the period C data is not relevant.

In the above example, the mezzanine format stored was the format of the highest quality. However, there may be instances where the mezzanine format may not need to be the highest quality. For example, if historical usage of viewing patterns shows that content is only viewed on a limited resolution device, then the mezzanine format may only need to be a lower resolution format, like SD instead of HD, which would result in significant cost savings.

In current nDVR systems, in order to assure the appropriate content format will be available, it is necessary to store many different content formats (for the same piece of content) for potential future playback. Storing many different content formats can become very expensive, especially if the consumer typically watches content in only a select number of formats based on the devices used.

The present disclosure provides methods to reduce costs associated with content storage on nDVR systems by storing data related to past content recording and viewing preferences, and using that data to predict which content formats are most likely to be viewed on a particular device. Using this information, it is possible to store only a limited number of content formats, thus reducing costs associated with content storage. In addition, if a content format is requested that is atypical for the user, an on-demand multi-rate transcoder can by employed to transcode the content to the appropriate format at the time of playback.

Another aspect of the present disclosure provides methods to further reduce costs associated with content storage by analyzing older content that is stored on the system, and deleting all forms of the content available except for the one(s) most likely to be viewed by the user in the future.

The foregoing description of various preferred embodiments have been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The example embodiments, as described above, were chosen and described in order to best explain the principles of the disclosure and its practical application to thereby enable others skilled in the art to best utilize the disclosure in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the disclosure be defined by the claims appended hereto.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A method comprising:

for each of a plurality of subscriber accounts, storing, via a network storage device, information related to a playback history of at least one content playing device associated with the respective subscriber account;

receiving, via a network digital video recorder scheduler, requests to record content from subscribers;

for each of the plurality of subscriber accounts associated with a request to record content, determining whether to record or retain the requested content for the respective subscriber account over a plurality of configurable time slots in accordance with the following:

during a first time slot:

identify one or more formats of the requested content to evaluate based on the playback history associated with the respective subscriber account;

determine a probability that the requested content in the identified one or more formats will be played for the respective subscriber account during the first time slot;

determine a cost to transcode the requested content for each of the determined one or more formats, where the cost to transcode is weighted based on the probability that an asset in the identified one or more formats will be played for the respective subscriber account in the first time slot;

determine a cost to record and store each of the identified one or more formats of the requested content;

for each format, compare the weighted transcoding cost to the cost to record and store the format;

record the requested content in the one or more evaluated formats if the weighted cost to transcode the requested content is greater than a cost to record and store the format; and

in one or more subsequent time slots, calculate a weighted transcoding cost for recorded formats and determine whether to delete any assets from storage for a respective subscriber during the respective one or more subsequent time slots.

2. The method of claim **1**, wherein the playback history includes information related to at least one of content playing device capabilities, previous content requested, time and date of session start, or trick play usage.

3. The method of claim **1**, wherein at least one recorded format is the highest quality format.

4. The method of claim **1**, further comprising storing the requested content in both a first format and a second format during the first time slot, and subsequently deleting the content in one of the first format or the second format in the one or more subsequent time slots after a predetermined period of time.

5. The method of claim **1**, further comprising:

receiving, via a network digital video recorder, the requested content in a plurality of formats; and

storing, via the network digital video recorder, the requested content in less than all of the received plurality of formats.

6. The method of claim **1**, further comprising transcoding a format of the requested content retained in storage into a required format for a content playing device associated with a subscriber, wherein the required format was at least one of not recorded in storage in the first time slot or deleted in the one or more subsequent time slots.

7. The method of claim **1**, wherein determining whether to record requested content in one or more formats is made individually for each subscriber account such that determining whether to record requested content in a particular format for a first subscriber account is a separate determination from whether to record requested content in a particular format for a second subscriber account.

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